Recurrent Holocene palaeoseismicity and associated land / sea level changes in the greater Anchorage area

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Aims and investigations undertaken

This project aims to analyse the evidence for multiple Holocene earthquakes to affect the upper Cook Inlet region over the past 5000 years using field evidence from Kenai, Ocean View (Anchorage) and Girdwood together with subsequent laboratory procedures. All activity for the period 1st May 2003 to 30th September 2003 comprised field investigations that occurred during July and August 2003. Laboratory work commenced on 1st October 2003. Subsequent analyses will: (1) apply quantitative transfer functions to estimate the magnitude of co-seismic submergence for each earthquake; (2) assess any evidence for tsunami deposits within the greater Anchorage area; (3) analyse the evidence for any pre-seismic relative sea-level rise and finally (4) investigate the coastal extent and recurrence intervals of great plate boundary ruptures.

Field Investigations

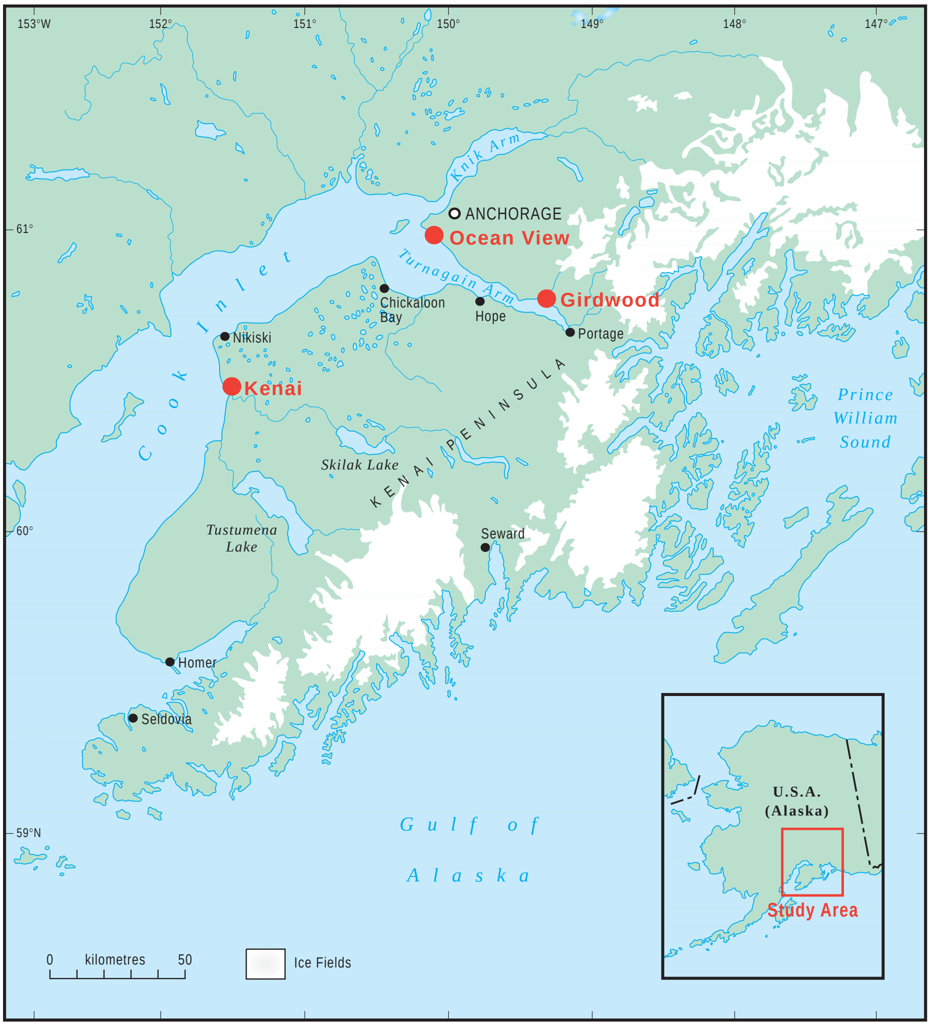

Figure 1
Location of field sites

Coring and exposed sections at Kenai, Ocean View (Anchorage) and Girdwood (figure 1) reveal laterally extensive multiple buried peat layers, typically characterised by sharp upper contacts with the overlying minerogenic layer. These characteristics suggest their formation by co-seismic land submergence followed by intertidal sedimentation during large plate boundary earthquakes. The plotting of marsh stratigraphy allows the selection and sampling of suitable peat-silt sequences using a variety of monolith tins and coring devices. Previous investigations (Hamilton, 2003; external grant award #02HQGR0075) show that using two sampling locations from each site for each event provides a more accurate estimate of co-seismic and pre-seismic relative land- and sea-level movements. This approach incorporates the various sensitivities of different coastal palaeoenvironments in recording relative land- and sea-level changes.

Kenai

Plafker (1969) suggests approximately 0.5 m co-seismic subsidence accompanied the 1964 earthquake at Kenai but this interpolation was from three observations, at Anchorage, Homer and Nikiski. The value for Nikiski, 15 km away, was 0.27 m submergence. In a more recent study limited to the decades leading up to the 1964 event, Zong *et al*. (2003) estimate the magnitude of co-seismic land subsidence at Kenai based on the application of transfer function techniques. They estimate the value to be 0.17 ± 0.12 m based on diatom data and 0.31 ± 0.21 m based on pollen.

A series of cores taken along a transect at Kenai reveals two extensive buried peat layers (figure 2). The upper boundary of the lowest peat and overlying silt varies in depth between 1.0 to 2.5 m below present marsh surface and it is sharp, apart from in Kenai-7 where it is transitional over 5 cm. Its thickness ranges from 10 to 128 cm and it is typically humified herbaceous peat with some *Sphagnum* species and bryophytes. It contains up to three distinct tephras, one likely to be the Hayes tephra, dated to 3591-4411 cal yr BP (Combellick & Pinney, 1995). This peat layer is absent in Kenai-9, probably due to its proximity to the small tidal channel.

In cores Kenai-10 and Kenai-14, a thinner peat layer (typically 4 cm thick, not on figure 2) occurs just above the upper boundary of the lowest peat, separated from it by a thin silt unit. A much thicker intervening clay-silt unit separates the uppermost peat from the lower peats.

The uppermost-buried peat layer, recording submergence during the 1964 earthquake (e.g. Zong *et al*., 2003) is present in Kenai-2 to Kenai-10 with traces of silt found within the peat in Kenai-11 and Kenai-12. The peat ranges in depth from 0.05 to 0.19 m below current marsh surface. It generally thickens towards the landward end of the transect, ranging from 8 cm by the riverbank to 27 cm at Kenai-10. It is typically brown herbaceous peat with some *Sphagnum* species and bryophytes. This peat contains up to two distinct tephras. Surface sediment grades from organic silt with tidal marsh vegetation in Kenai-1 to a progressively thicker surface peat from Kenai-9 landward. At Kenai-16, a floating mat of vegetation occurs from the surface down to a depth of 0.83 m.

This sequence of two extensive buried peat layers sharply overlain by silt suggests this area may record relative sea-level changes associated with periods of the earthquake deformation cycle (EDC) model (e.g. Combellick, 1994). Coarser sand layers do not overlie any of the buried peat surfaces, suggesting that there is no evidence for any tsunami deposits.

Ocean View

During the 1964 earthquake Plafker (1969) records approximately 0.7 m sudden co-seismic subsidence at Anchorage, although his estimates based on initial mapping in the summers of 1964 and 1965 vary between 0.7 and 1.5 m. Preliminary analysis by Noble (2000) estimates the magnitude of change to be between 0.2 and 0.5 m.

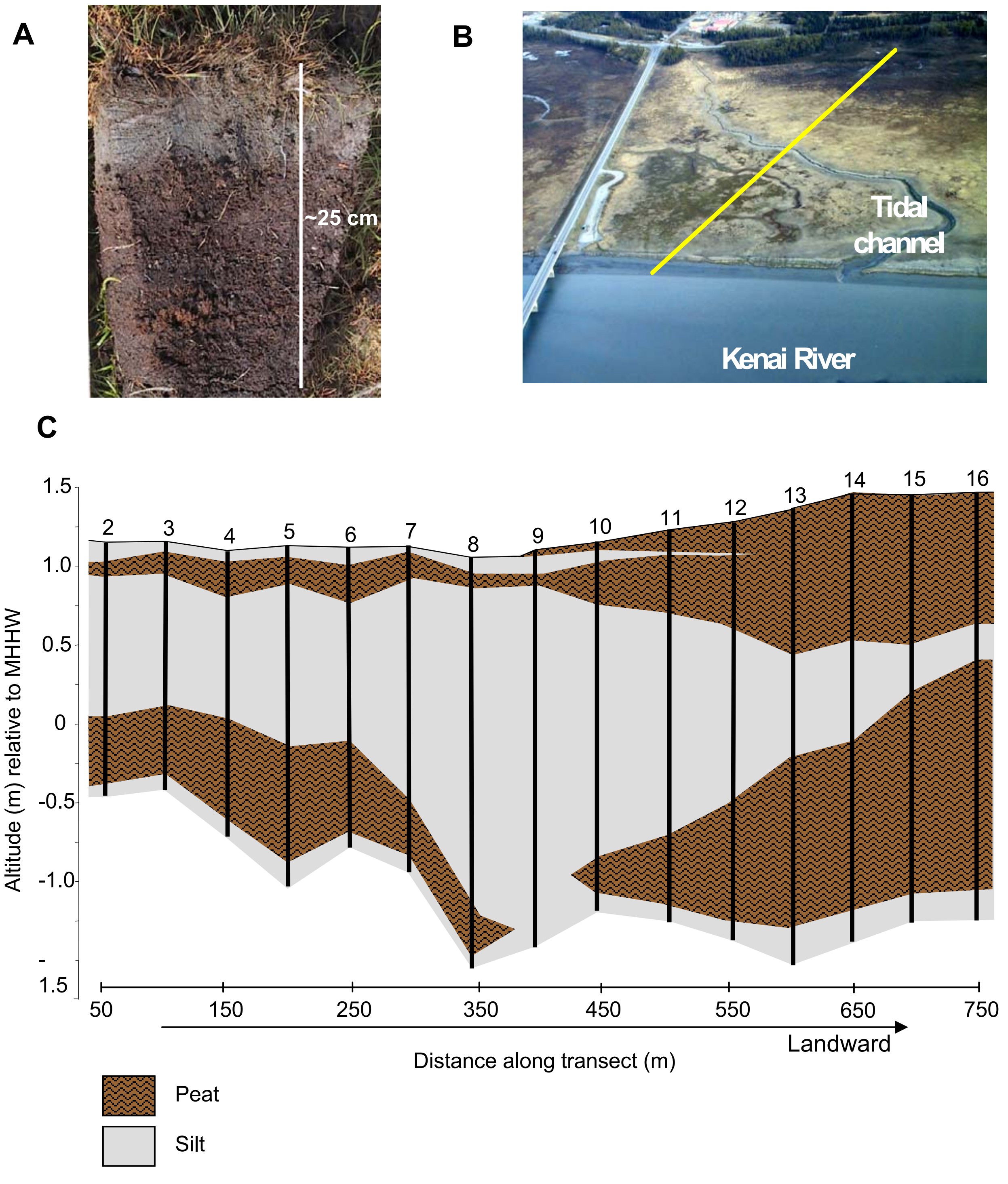

Figure 2

Stratigraphy at Kenai

(A) The uppermost peat-silt boundary associated with the 1964 event at Kenai-4

(B) The coring transect across the marsh surface

(C) The litho-stratigraphy of the marsh

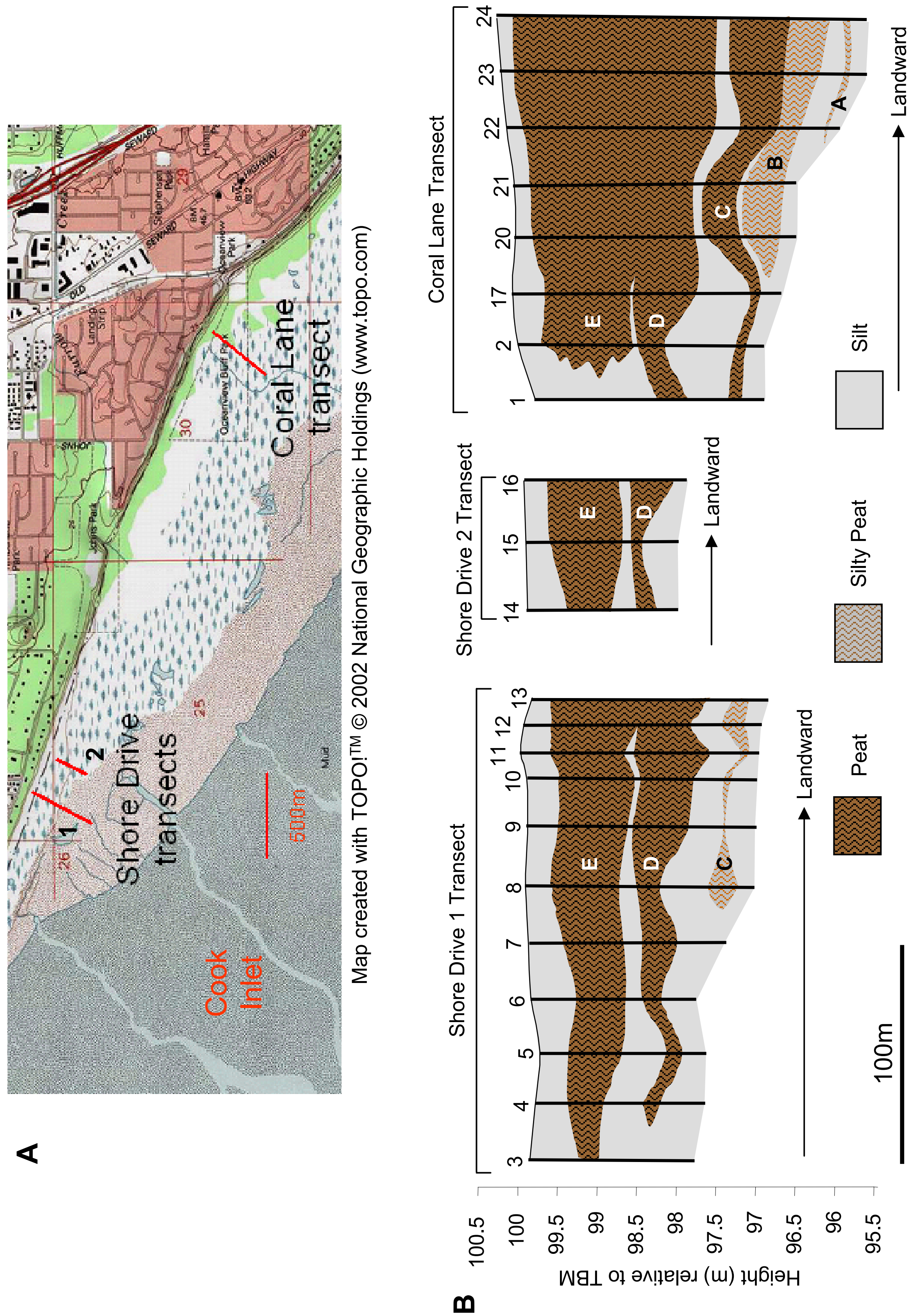

Figure 3

Ocean View, Anchorage with (A) showing the location of the coring transects and (B) the litho-stratigraphy of the marsh

Coring along three transects at Ocean View (figure 3) reveal up to five buried peat layers with sharp upper contacts. A maximum of three buried peat layers are found at Shore Drive and up to five at Coral Lane. Each peat layer is given a name (A at the base to E closest to the surface) to make descriptions of stratigraphy easier.

Co-seismic submergence associated with the 1964 earthquake followed by intertidal sedimentation buried peat E (previous award #02HQGR0075; Noble, 2000). This herbaceous peat layer is typically 27 to 156 cm thick and the peat-silt boundary is typically found 0.2 to 0.6 m below present marsh surface. Towards the landward extremes of both transects this peat merges with the second buried peat layer, peat D. In core locations close to the Cook Inlet peat D is a distinct buried peat layer. Its burial results from co-seismic submergence during the penultimate great earthquake to affect the greater Anchorage area (previous award #02HQGR0075). This herbaceous and bryophyte peat unit is generally thinner than peat E (ranging between 14 and 94 cm) and is typically found 1.25 to 1.75 m below current marsh surface. Both occur at similar depths along the three transects. This project builds upon the previous award #02HQGR0075 and extends the analysis further back in time to include earlier Holocene events.

At Shore Drive only one additional silty peat layer is found along transect 1 (peat C). It is thin, with a maximum thickness of 28 cm with its upper peat-silt boundary occurring 2.25 to 2.75 m below present marsh surface.

In addition to peats D and E, the Coral Lane transect records three older buried peat layers. Peat C occurs at a similar depth below marsh surface to that recorded at Shore Drive, but it is better developed and the herbaceous and bryophyte peat contains less silt. Towards the landward limit of the Coral Lane transect, peat C merges with peat B. Peat B has multiple bands that comprise layers of herbaceous peat with varying amounts of silt enrichment. At the base of the sequence, 4.0 to 4.4 m below present marsh surface, a thin silty herbaceous peat (peat A) occurs reaching a maximum thickness of 9 cm.

Girdwood
Plafker *et al*. (1969) suggest 1.5 m regional subsidence and up to 0.9 m local subsidence of unconsolidated sediment accompanied the 1964 event at Girdwood. Previous work at this site (e.g. Combellick, 1994; Hamilton, 2003; Shennan *et al*., 1999; Zong *et al*., 2003) together with last years award (#02HQGR0075) indicates that the transfer function technique accurately estimates the amount of co-seismic submergence for this event and for the penultimate event approximately 800 cal yr BP. This project extends this record further back in time with the sampling of an additional six possible events.

Exposed sections and coring across the mudflats at Girdwood reveal multiple buried peat layers at varying depths below present day marsh surface (figure 4). The 1964 event (recorded by the submergence of peat H) and penultimate event (peat G) exposed within the bank section was studied as part of award #02HQGR0075 in 2002-2003. Below peats G and H are an additional six buried peat-silt couplets with peat layers ranging in thickness from 6 to 25 cm. Peats A, B, E and F are herbaceous and bryophyte peats where as peats C and D are less well developed and are silty peats. All are laterally continuous and have sharp upper contacts. The collection of samples through this entire sequence for microfossil analyses and radiometric dating together with the application of a transfer function allows an evaluation of the four phase EDC model, an estimate of earthquake recurrence intervals, calculation of the magnitude of co-seismic submergence and investigates

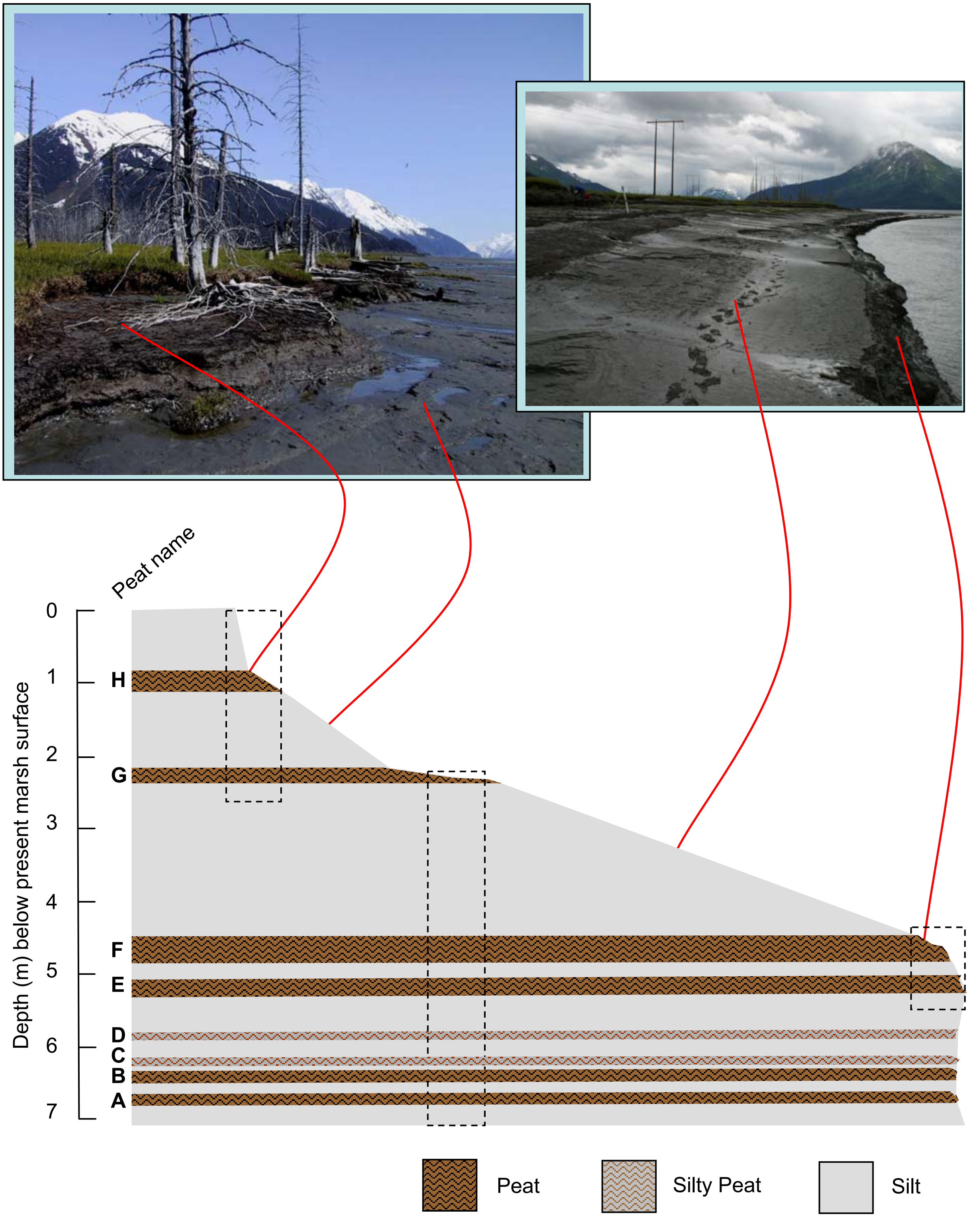

Figure 4

Section showing the buried peat layers beneath the marsh surface at Girdwood. Photographs illustrate the topography of the surface at various locations down the marsh. Dashed boxes show where samples for microfossil analysis and radiometric dating were taken.

whether pre-seismic relative sea-level rise is present before each co-seismic event through the Holocene.

Laboratory Work

Microfossil analyses and sampling for radiometric dating started in October 2003.

Planned activities

Quantitative reconstruction of relative sea-level change requires a comprehensive contemporary training set to allow the development of a regression model of diatom assemblage against altitude (m) relative to mean higher high water. Such a model was developed under our previous award (#02HQGR0075) using contemporary diatom samples and associated environmental variables from Kenai, Girdwood and Ocean View. The application of this model to the new data collected during this current funding year allows the calibration of fossil data and reconstruction of relative sea-level change through numerous earthquake deformation cycles affecting the greater Anchorage area during the Holocene in order to address the aims outlined in the introduction.

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Non-technical summary

New field investigations at Kenai, Ocean View (Anchorage) and Girdwood together with subsequent laboratory procedures will: (1) analyse the evidence for multiple Holocene earthquakes to affect the upper Cook Inlet region over the past 5000 years; (2) apply quantitative transfer functions to estimate the magnitude of co-seismic submergence for each earthquake; (3) assess any evidence for tsunami deposits within the greater Anchorage area; (4) analyse the evidence for any pre-seismic relative sea-level rise and finally (5) investigate the coastal extent and recurrence intervals of great plate boundary ruptures.